POWER CONTROL FOR ACTIVE LINK
QUALITY PROTECTION IN CDMA NETWORKS

5   FIELD OF THE INVENTION

The present application claims priority based on the provisional application Serial No. 60/169,849, filed on December 9, 1999, the entire contents of which are incorporated by reference. The present invention relates to protecting a Code Division Multiple Access (CDMA)

10   data network from excessive interference in order to maintain the quality of service of the data network. A power control approach is disclosed to scale the power of all active links to achieve link protection and improved tolerance to interference.

15   BACKGROUND OF THE INVENTION

Broadband CDMA systems, in the near future, will provide a wide range of multi-media services including voice, data, and video. With multi-media traffic, users present the network with a range of bandwidth and quality of services (QoS) requirements.

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The performance of a CDMA system is interference limited. Interference can cause disruption in the service of dedicated bandwidth or circuit data users who have been admitted into the system and guaranteed frame error rate and throughput targets. In order to provide the quality of service ("QoS") guaranteed to data users, the interference in the system must be tightly

25   controlled. Multi-access interference can be regulated by controlling the transmit powers of the users. Power control techniques that are designed only to combat fading, suffer the problem that an active new user can cause the signal to noise ratios of operational users to drop below their required threshold. Therefore, power control techniques must be designed to adjust the power when new users are admitted to the system, to maintain their guaranteed quality of service and

30   for active link quality protection.

A detailed mathematical analysis of the affect of transmit power on the interference margin in a communications channel and how the link protection algorithm of the present invention was derived is presented in the following references, which are hereby incorporated by

35   reference in their entirety:

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1.   D.V. Ayyagari and A. Ephremides in Power Control for Link Quality Protection in Cellular DS-CDMA Networks with Integrated (Packet and Circuit) Services. MOBICON 99 (Conference) September 15, 1999.

2.   D.V. Ayyagari, Capacity and Admission Control in Multi-Media DS-CDMA Wireless Networks. Ph.D. Dissertation, University of Maryland, College Park, 1998.

SUMMARY OF THE INVENTION

In Code Division Multiple Access (CDMA) systems the capacity is a function of the total interference on the system, which in turn depends on the received powers of all the users sharing the same frequency spectrum. A dynamic power control algorithm is used to control the received signal strength at the base station of a CDMA network. The transmit power levels of users are controlled by up/down commands issued on a forward link from the base station.

The base station dynamically computes the maximum received signal strength available from each user including the effect produced by path gain over the signal path to the base station. The base station then computes the minimum power required from each user that will meet the QoS and frame error rate requirements of each user. The maximum to minimum power ratio is determined for each user and the power ratio closest to unity, the weakest link, is determined. The weakest link power ratio is then used to scale upwardly the minimum power level of each user to provide the optimal operating power that will meet each user's "Quality of Service" (QoS) and frame error rate requirements with the lowest addition of interference to the network.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the steps in the algorithm of the present invention.

DETAILED DESCRIPTION

For simplicity, the present invention will be described as used with a cellular communication system having mobile user in communications with a cell base station. The inventive system is implemented at the base station but it is applicable to both the forward and reverse links. Forward = base to mobile, while reverse = mobile to base.

The link protection process begins at 5 of Figure 1, where each user of the network is currently operating at individual power levels sufficient to meet its signal to noise ratio and quality of service requirements. The transmit power levels of the users are controlled by the base station via up/down commands issued on the forward link. At this step, the mobile units are operating at a power greater than the minimum required for their signal to noise ratios but less than or equal to their peak transmit power capability which is fixed by battery power. The weakest link needs a minimum transmittal power almost equal to the maximum transmittal power.

The base station at step 7 dynamically calculates the path gain for each of the mobile units. This can be done by the base station issuing a command to the mobile unit to transmit at a known power level and then measuring the received power. Received power = T. x path gain.

At step 9, the base station computes the maximum received power possible from each mobile unit. At connection or communication set-up, the mobile unit identifies the type of mobile unit being used. The peak transmit power capability of each class of mobile unit is known to the base station. From the path gain measurements, the base station computes the maximum received power possible from each mobile user. The maximum received power equals peak transmit power times path gain.

At the next step 11, the base station computes the minimum received signal power it needs to receive in order to maintain the quality of service and frame error rate requirements. The limitations of the base station are known so the minimum received signal must be strong enough to overcome these limitations to meet the user's service requirements. The minimum received power can be computed using the same equation used to solve for maximum received power but substituting minimum received power, which is known, and solving for minimum

transmit power. Like the maximum power, it can also be determined by sending command signals from the base station ordering the mobile unit to reduce power until the signal to noise ratio is reached where the mobile unit is just meeting its quality requirements. Testing in this manner, however, adds unnecessary noise to the data link.

5   A power ratio is then determined at 13 by dividing the maximum received power of each mobile unit by the minimum received power each mobile unit needs to meet its signal to noise ratio and quality requirements. The lowest power ratio determined for all of the mobile units, the power ratio of the weakest link, is selected for use as the scaling factor. The weakest link needs

10   a minimum transmittal power almost equal to the maximum transmittal power.

The lowest power ratio or scaling factor is used at 15 to raise the minimum transmit power of all of the active mobile units. The base station raises the powers of all active mobile units by the up/down commands on the forward link by the scaling factor.

If the network is not heavily loaded, it is possible to raise the operating power of the active users on the network. Therefore, it is necessary to determine an alternate scaling which does not raise the user powers beyond what is necessary. Let $\hat{B}$ be the required interference margin. Then the scaling factor a that would provide the interference margin $\hat{B}$ can be

20   determined as follows:

$$\hat{B} = \frac{\hat{a}s_i^{min}}{T_i} - \sum_{j \neq i} \hat{a}s_j^{min} - \eta$$

$$\hat{a} = \frac{\hat{B} + \eta}{\dfrac{s_i^{min}}{T_i} - \sum_{j \neq i} s_j^{min}}$$

where i is the index of the code that has lowest minimum power s_i^{min}. This results in the lowest

25   power vector, which maintains link quality and provides the desired interference margin $\hat{B}$.

In accordance with the Telecommunications Industry Association's interim standard IS-95 the power control algorithm can issue update instructions at the rate of 800 updates/second to each active mobile user. Operating at approximately 850 MHz the path gain for a mobile unit

can change in a matter of inches. Interfering structures and foliage have a significant affect on the path gain.

Knowing the path gain as determined by the base station, it issues a command for each active mobile unit to transmit at a known power. (The base station, upon initial contact with the mobile user, ascertains the type of equipment the mobile unit is using. The base station has stored in memory the characteristics of the mobile unit and what its power capability is for the unit.) The Base station then measures the power received. Knowing the path gain and the received power, base station determines the maximum received power possible at the base station for each user's mobile unit.

The link protection system will preferably be used continuously while the network is in operation to dynamically determine the operating power of the active mobile users since the power ratio or scaling factor and the path gain varies continuously as a user moves relative to the base station. The system is proven to yield significant improvements in capacity while maintaining the quality of service guarantees made by the network to high capacity users currently active on the system.

While the invention has been disclosed in connection with the preferred embodiments shown and described in detail, various modifications and improvements thereon will become readily apparent to those skilled in the art. Accordingly, the spirit and scope of the present invention is to be limited only by the following claims.